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WASTES IN THE PRODUCTION AND UTILIZATION OF NATURAL GAS AND MEANS FOR THEIR PREVENTION

BY

RALPH ARNOLD
AND
FREDERICK G. CLAPP

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WASTES IN THE PRODUCTION AND UTILIZATION OF NATURAL GAS, AND MEANS FOR THEIR PREVENTION.

By Ralph Arnold and Frederick G. Clapp.

DISTRIBUTION OF NATURAL GAS.

Natural gas occurs in commercial quantities in 23 States of the United States, and the production in the calendar year 1911 was 508,353,241,000 cubic feet, having a total value of $74,127,534. The estimated total area of the gas fields in the country is given as 9,365 square miles.[a]

The areas of natural-gas production can be classified in seven principal regions and fields, as follows:

1. Appalachian region, which includes the fields of New York, Pennsylvania, southeastern Ohio, West Virginia, Kentucky, and Alabama.
2. Trenton rock, or Ohio-Indiana field.
3. Clinton sand, or central Ohio field.
4. Mid-Continent or Kansas-Oklahoma field.
5. Caddo field in northwestern Louisiana.
6. The Texas fields.
7. The California fields.

HISTORY OF NATURAL-GAS DEVELOPMENT.

Natural gas has been known in foreign countries since ancient times. Before and during the time of Julius Caesar there was a famous "fontaine ardente," or burning fountain, near Grenoble, France. In China there were gas wells, drilled 2,000 feet deep for salt, in early centuries. The gas was transported in bamboo pipes to the place of consumption. In Japan gas wells were known as early as 615 A. D. The region of eternal fires, in the Apsheron Peninsula on the shore of the Caspian Sea, where inflammable gases issued from rock fissures, was known at least as early and the fires were worshipped by the Parsees. At an early date the city of Genoa, Italy, was lighted by gas brought from the wells of Amniamo in Parma.

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[a] Day, David T., Mineral Resources U. S. for 1910: U. S. Geol. Survey, 1911, p. 279.

The first recorded instance of natural-gas utilization in the United States was in 1821, at Fredonia, N. Y., where a well only 27 feet in depth supplied enough gas for 30 burners, and the hotel was illuminated from this well on the occasion of Gen. LaFayette's visit in 1824. The first use of natural gas for manufacturing purposes is believed to have been in 1863, at East Liverpool, Ohio. The first natural-gas pipe line was built in 1876 to supply Titusville, Pa., from a well 786 feet deep, and the same year gas was brought to Pittsburgh from a field 19 miles distant in Butler County for use in a rolling mill. During succeeding years the Pennsylvania, Ohio, New York, and West Virginia fields were developed, and these three States still come in the first rank of gas-producing States, having produced more gas in 1910 than in any preceding year.

In the Ohio-Indiana or Trenton rock field natural gas was discovered in 1884 at Findlay, Ohio, and the Clinton sand field of central Ohio was discovered in 1887 at Lancaster. The Trenton rock field has ceased to be an important producer, but the fields that obtain their production in the Clinton sand have been better managed and are still among the greatest producers known. In 1911 pipe lines in Ohio were still being built, and the Clinton sand production was the largest in the history of the field.

The first paying gas wells in Kansas were drilled in 1882, but important developments did not take place until 1894. At the present writing (1912) the supplies of the Kansas fields are waning fast. In Oklahoma and Louisiana no important natural-gas developments took place until within the past seven years. The development of gas in Texas was coincident with the search for oil, the principal discoveries being made from 1901 to 1903. Natural gas was utilized near Stockton, Cal., as early as 1890, but the big producing wells of that State have been drilled in connection with the oil developments of the past 10 years.

WASTES OF NATURAL GAS.

The history of the natural-gas industry of the United States is an appalling record of incredible waste, but it must be told, in order to explain the need for the remedies proposed.

There was evidently no great waste of gas in this country before 1873, as no large gas fields had been discovered, although gas was always wasted in oil production. In 1878 a well of great volume and pressure was struck at Murraysville, Pa., 20 miles east of Pittsburgh, and the gas from this well was allowed to flow to waste for three years with no effort to check it. Up to this time the belief that natural gas was inexhaustible, seemed to be universal, just as in later years a similar opinion prevailed regarding the forests, coal, and many minerals, and hence it was not until 15 or 20 years after the first utilization of gas that the pronounced decline of production caused the truth to dawn upon producers and consumers—that the supply was indeed limited.

The waste of natural gas has drawn the attention of the entire country, and because the waste threatens the life of gas fields it has prevented many investors from building plants in the various fields, thereby depriving the localities of increased population and wealth. In considering the question of waste, it must be understood that the geologic occurrence of the gas in the sandstone, sand, or limestone resevoirs is such that the flow of gas from one well causes a decrease in the flow of others and a reduction of the supply throughout the entire field.

The various ways in which natural gas is wasted may be classified as follows:

(*a*) In drilling and casing wells.
(*b*) From high-pressure wells.
(*c*) In oil production.
(*d*) Lack of proper care of wells.
(*e*) In transportation.
(*f*) In utilization.
(*g*) Improper plugging of wells.

WASTE IN DRILLING AND CASING WELLS.

Instances are common where carelessness and indifference in drilling have resulted in waste of gas from formations penetrated above the regular sand. One method of waste of this kind is described by McDowell[a] in the following words:

> In drilling for oil in some districts large gas wells are found in sands above the oil sands. In many instances, the pressure and the volume of such wells are so great as to prevent drilling to the lower oil-bearing sand until the well has been allowed to exhaust its gas production into the air, sufficient to permit the resumption of drilling. Usually this criminal waste is allowed to continue until the gas-bearing sand is nearly, if not quite, exhausted.

In other instances, if the formations are loose, the gas sand fairly shallow, the pressure great, and the proper precautions are not taken in setting the casing, the gas may escape around the casing, loosening the ground rapidly, and ultimately gaining sufficient volume and pressure to blow the casing from the well. Such "blowouts" have happened a number of times in the Texas and Caddo fields. They are likely to occur in the first wells drilled in any field, before the conditions attending the gas pockets are generally known. Some excuse may exist for the occurrence of one such "blowout" in a new field, before the presence of the high-pressure gas pocket is known, but there is usually little reason for a second or a subsequent "blowout" in a field, because precautions can be taken to prevent it.

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[a] McDowell, J. C., The conservation of natural gas: Proc. 5th Ann. Meeting, Nat. Gas Assoc. of America, 1910, p. 108.

Waste in drilling is not so great as formerly, because at the present time drillers have usually every facility at hand to close a well as soon as completed. By proper preparation most wells can be packed, tubed, and shut in within two hours. According to the conservation commission of Louisiana, the waste from the two principal "wild" wells in Louisiana had its beginning more from a lack of knowledge of what precautions would be effective than from negligence or indifference. The waste from the first big gas well encountered in drilling for oil in the Buena Vista Hills field in California was due to the unexpectedness of the great flow and to local inexperience in handling such pressures. This well was controlled only after a Texas operator had been engaged to do the work.

WASTE FROM HIGH-PRESSURE WELLS.

In the early days of a gas field, the pressures may be so great that a well can not be capped with the means available on the ground at the time. Moreover, there may be, and often is, no market, because the pipe lines of the natural-gas companies have not reached the field. In such cases many of the wells are allowed to blow to waste with no attempt to stop them.

Some examples of such "wild" wells have been the Caney Fork well in Kansas, the Homewood well at Pittsburgh, Pa., the Oil City wells in Louisiana, one or two California wells, some Oklahoma wells, and others in nearly every gas field.

Doctor White[a] states that:

> From one well in eastern Kentucky there poured a stream of gas for a period of 20 years without any attempt to shut it in or utilize it, the amount of which it has been figured was worth at current prices more than $3,000,000.
>
> In my own State of West Virginia only eight years ago not less than 500,000,000 cubic feet of this precious gas was daily escaping into the air from two counties alone, practically all of which was easily preventable by a moderate expenditure for additional casing.

In Ohio, Indiana, Pennsylvania, and other parts of West Virginia there was in the past such waste as is cited by White; but it has long since ceased, owing to the business-like attitude of the larger companies and the efficient State regulation in some cases.

The most notorious waste at present is in Oklahoma, Louisiana, and California. The commission on the conservation of the natural resources in Louisiana, after an exhaustive examination of the situation in the Caddo field, found that the waste approximated "75,000,000 cubic feet per 24 hours, an amount equal to 20 times what the city of Shreveport uses now in the same space of time and equal to one-twentieth of the amount consumed by the entire United States." It also found that the value of the gas wasted from a single "wild" well in that State was in excess of $2,000 per day. There were three principal wells in the Caddo field from which the greater part of the waste occurred. They were known locally as the "dry gas well," the "mud gas well," and the "salt gas well." Two of these have been closed by the owners, thus proving that closure is feasible. No attempt has been made to close the other, and when visited by Mr. Clapp in February, 1912, it consisted of a crater perhaps an acre in extent, in the center of which the gas was forcing a geyser-like mass of mud and water to a height of 20 or 30 feet. During much of the time this well is burning. The gas from this well has been going to waste for three years. Two other wells having an estimated volume of 20,000,000 or 30,000,000 cubic feet per day blew out and burned for one or two years. In the Caddo field at least 400,000,000 cubic feet of gas has at certain times been wasted daily, practically all the waste being preventable.

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[a] White, I. C., address at Conference on the Conservation of Natural Resources, May 13, 1908.

McDowell states that the daily waste of gas in Oklahoma by escape into the air is equivalent to at least 10,000 tons of coal daily, and he states that 80 per cent of this loss is preventable.

WASTE IN OIL PRODUCTION.

McDowell estimates the gas wasted in oil production in the Oklahoma fields during the past five years to be more than the value of all the oil produced in that time. He states that:

> Many gas sands are entirely free from oil, while gas in varying quantities is always found in oil-bearing sands. All flowing oil wells are also gas wells of more or less volume. It is not uncommon to find an oil well producing 50 to 100 barrels of oil also producing from five to ten million feet of gas per day, the gas at a low rate being four to five times the value of the oil.
>
> The oil producer in his insane greed for riches, fortified by the long-established custom, is the principal transgressor. Having no immediate market for the gas of the upper sands, he allows it to exhaust itself in the air until the pressure is reduced to a point where he can resume drilling; then he penetrates the oil sand where he may, and frequently does, develop a well producing from 5 to 10 barrels of oil and from five to ten million cubic feet of gas, the latter having a fuel value at a very low figure per thousand feet of many times the value of the oil. In nearly every new oil development the oil wells produce gas from the oil sand in considerable quantities. The oil producer, if in need of power, uses what gas he requires for power purposes and turns the balance loose, looking on any surplus gas as a nuisance, to be gotten rid of, claiming the right to do as he pleases with his own product, and in the absence of legislation on the subject he seems to be acting within his rights.[a]

According to the Oil and Gas Journal, of March 6, 1910, a well in the Preston field, near Okmulgee, Okla., was at that time permitted to run wild at the rate of 36,000,000 cubic feet of gas per day. It had then been opened for several weeks in the hope that it would become an oil well. There was no way to take care of the gas and the pressure was so great as to make it impossible to operate tools in the hole. On the date mentioned the well had begun to spray oil, and the gas pressure had declined somewhat, thus indicating that it would probably make a good oil well. It was calculated that a total value of $22,680 worth of gas escaped into the air in the three weeks that the well had run wild.

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[a] Op. cit.

Another well in the same field was estimated to have a production of 40,000,000 cubic feet per day, and this was allowed to escape into the air for 10 days, entailing a loss of $12,000. In the Glenn field there was similar loss of gas, although on a smaller scale. "The result was that before the Glenn field was three years old it was without sufficient gas for its own necessities, and gas had to be pumped into the field from outside sources." These are only a few of the examples that might be mentioned from Oklahoma.

In drilling for oil in the Buena Vista Hills field, California, one gas well was opened that wasted at least 55,000,000 cubic feet per day for three months before it was finally got under control. At least 5,000,000,000 cubic feet of gas, valued at 25 cents per 1,000 cubic feet, or $1,250,000, was lost from this one well alone.

The commission on the conservation of natural resources appointed in Louisiana found that 15,000,000 to 20,000,000 cubic feet of gas, or about one-fourth of the entire waste in the Caddo field, came from producing oil wells and from abandoned gas and oil wells, and "that in a number of oil wells a small quantity of oil is obtained at the expense of a gas waste many times more valuable."

The custom of wasting gas from oil wells originated in the early days of the oil industry in Pennsylvania, when gas was universally considered a nuisance, and, as Day has stated,[a] "developed a hostility toward natural gas on the part of the oil-well driller, which has increased rather than diminished up to the present time. It is to this hostility that the present waste of natural gas in oil regions is due." Gas was originally considered not only a nuisance but a menace by the oil driller, because at many wells, after the gas was packed off, it caused destructive explosions.

In the State of West Virginia there has been a great deal of waste in the past, owing to the fact that the gas from the Gordon Stray sand, which has a rock pressure of 1,100 pounds, escapes, together with the oil obtained from the Gordon sand 40 to 50 feet deeper. According to White,[b] 12,000,000 to 15,000,000 cubic feet of gas daily is sometimes wasted to save 5 to 10 barrels per day of oil. This waste could be prevented, as suggested by White, by setting an extra string of casing in the 10 to 30 feet of shale that separates the Gordon Stray sand from the Gordon sand. The cost of this casing would be only $1,000 to $1,500 per well and it would be possible to save this sum in a few days under ordinary conditions, after a market had been found for the gas. Most of the oil companies, however, have not cared to go to the expense of the extra casing.

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[a] Day, David T., Natural-gas resources of the United States: U. S. Geol. Survey Bull. 394, 1909, p. 58.

[b] White, I. C., Petroleum and natural gas in West Virginia: Proc. Nat. Gas Assoc. of America, 6th Ann. Meeting, 1911, p. 194.

In certain of the southern California fields the gas that accompanies the oil is exceedingly rich in gasoline, but up to a short time ago practically all of this gas, with the exception of some used locally for fuel, went to waste. As it has been found that at some wells the value of the recoverable gasoline in the gas is worth as much as 20 per cent of the oil produced from the same well, it is not extravagant to estimate the loss of gasoline—the most desired constituent of the product—in the wasted gas in California at 10 per cent of the value of the oil produced in the southern California fields up to 1912, or a clear waste of about $3,000,000 to $4,000,000. The value of the wasted gases carrying minor amounts of gasoline, but useful for fuel purposes, will bring the total loss up to fully 5 per cent of the value of the total oil produced in the State, or $8,000,000.

WASTE OWING TO LACK OF PROPER CARE OF WELLS.

The term "waste" should properly be used to include not only the amount of gas actually dissipated, but also that which after discovery is placed beyond the possibility of recovery. In other words, there is a loss to the community if a well is not properly exhausted of its gas. There are undoubtedly many instances of carelessness and indifference in taking care of the product and of the well after drilling.

A large amount of gas has been placed beyond recovery by wells having been allowed to flow gas at their full capacity, thus causing the pressure to drop rapidly, and allowing adjacent pools of salt water to flood out the gas from that particular part of the sand. This is true in all fields in wet sands, but especially so in Oklahoma.

In this connection the common method of blowing off wells should be mentioned. At many wells the gas is allowed to blow into the air for half an hour every morning in order to free the well of water. This is unnecessary, as siphon arrangements can be made to do this work, assisted, if need be, by pumping.

In California the gas and water sands above the oil sands are usually cased off with the same string of pipe, thus allowing the water free ingress into the gas sands to their resultant ruination. The loss on this account is slight, however, as compared with the loss of the gas escaping from the oil sands themselves.

WASTE IN TRANSPORTATION.

The waste of gas in transportation is a minor factor, but should be mentioned. It is due mostly to leaky pipe lines.

WASTE IN UTILIZATION.

Although the waste through improper utilization is diminishing, the fact remains that many millions of cubic feet are wasted daily by being sold at a flat rate, and by being burned in imperfect devices.

In a great many cities it was the custom in the past to sell gas at a flat rate, or at a certain rate per month, instead of selling it by the thousand feet through the use of meters. The majority of cities now supply gas through meters, but there are still some which do not. According to the Petroleum Gazette, of November, 1909, there were no meters in the town of Humboldt, Kans., and as a result at least half the lights in town were left burning all night. Gas was being sold in Humboldt at the low rate of 20 cents per burner per month. Many such examples might be found by going back 10 years, but at present this form of waste has been largely remedied by installing meters.

Another form of waste in utilization consists in piping the gas back into an oil well in order to force the oil to the surface, the gas generally being allowed to escape when it finally reaches the oil tank. Another wasteful use is to burn gas under a boiler for generating steam, as greater economy can often be obtained by burning in an internal-combustion engine. There is an excuse for burning the gas for steam generation in drilling wells, as up to date no internal-combustion engine has been developed that can compare with the steam engine for drilling purposes.

It is a fact that when "from 40 to 60 cubic feet of gas per horsepower is used under a boiler for driving a steam engine the same power can be developed by the consumption of from 9 to 15 cubic feet per hour in a gas engine of equal reliability and cost of maintenance." Hence, the use of gas under steam boilers at power plants should not be encouraged.

To burn flambeaux in front of a dwelling or elsewhere, as is done in the oil fields, should be condemned. Gas is still left burning day and night in hundreds of places in Oklahoma, and in several of the fields in California. In a visit to the Glenn pool, in 1912, gas was seen burning during the day at a great number of points in the field.

WASTE OWING TO IMPROPER PLUGGING.

Several States have laws requiring the gas inspector to supervise the plugging of all dry or abandoned wells. Some States have no such laws, and in these the plugging is generally improperly done, with the result that at many wells water from a water sand is permitted to flow into a gas sand, drowning out the gas supply. Although the larger companies appreciate the problems involved and take particular care in their work, the smaller companies and the individual operators generally consider it easier and cheaper to pay little attention to plugging, once the well is abandoned and the casing drawn.

There have been many wells with a production of 10 to 20 barrels of oil and 5,000,000 to 10,000,000 feet of gas per day at which the oil was saved and the gas allowed to escape unchecked.

DECLINE AND FAILURE OF FIELDS.

Whatever the prevailing opinion may be, the fact remains that natural gas is not inexhaustible; only a comparatively limited amount is stored in certain porous formations, and when this is once exhausted no more is forthcoming in commercial quantities. Hence the history of any gas field records a rapid decline in pressure and volume. The permanence of the yield of the Pennsylvania, West Virginia, and Ohio fields has been due to the great number of fields and of sands which could be tapped in turn; but in fields in other regions the sands are fewer in number, and a similar permanence can not be expected.

The decline in pressure in various fields of the United States has been marked. One of the most rapid declines was in the northern Indiana fields, where the pressure dropped from 400 pounds in 1886 to 50 pounds in 1902. Thus those fields were practically exhausted within 15 years. McDowell states that three times as much gas was wasted in those fields as was used.

Other quick declines have been in Kansas and Oklahoma. In the latter State the rock pressure of the gas in the Hogshooter field is (1912) dropping off at the rate of a pound a day, according to Harry H. Breene, gas inspector of Oklahoma, and only recently the volume of the Copan field in the same State dropped from 300,000,000 feet per day to 100,000,000 feet per day in one year, during which time the number of wells was doubled. The producing areas of these fields are, however, rather small. In Louisiana a similar decline is noted.

One case of exceedingly rapid decline in California was that of a well in the Midway field. The 16-inch casing of this well tapped a stray gas sand at a depth of 540 feet; the flow was 50,000,000 cubic feet per day for a few days, and then became unimportant. The pressure of the gas was only 20 to 25 pounds when tapped and 15 pounds when shut off, but the size of the hole permitted a large flow.

EFFORTS TO PREVENT WASTE.

Several of the States have passed laws restricting the waste of gas; but these have generally been put into effect too late to prevent the worst dangers. A few broad-minded men, including operators and geologists, had sounded a warning from time to time, but the real movement for the conservation of gas may be said to have begun when I. C. White, State geologist of West Virginia, delivered his address before the conference which convened in Washington on May 13, 1908.

White had already been working for years to induce the West Virginia legislature to pass necessary laws but without avail; the influence of his address, however, has been most beneficial and far-reaching. One of the foremost gas producers to appreciate the necessity for conservation is McDowell, who in 1910 delivered an address urging the Natural Gas Association of America to take some steps for the prevention of waste.[a] After attention was thus called to the great waste a committee was appointed by the association, with Mr. McDowell as chairman, to consider ways and means of remedying the evils.

As long ago as 1899, Dr. Orton had advocated the proper use of natural gas.[b] In a publication of the United States Geological Survey on the subject of conservation, Day summarizes the natural-gas resources, their waste and conservation.[c]

Several States have had conservation commissions. One form of conservation advocated has been the withdrawal from entry of certain public lands that are believed to be mineral lands, these to be held in trust for future generations. This withdrawal can rarely be effective as true conservation, because such lands are usually of such limited extent that their withdrawal can not have much effect on the national supply of natural gas, and true conservation lies in using gas to the best advantage, not in rendering it useless.

The writers have no intention of suggesting any plans looking toward the throttling of legitimate gas development or the hoarding of gas for use by future generations; they believe gas should be conserved where this can be done without diminishing its economical use and without doing an injustice to the producer. In other words, the purpose of this report is to suggest measures for preventing the waste and injudicious use of the gas, by showing what has been done in the past and what may be done in the future.

Since there are so many misapprehensions as to the purpose, intent, and effect of the conservation movement, it seems well to insert a brief statement as to the meaning of conservation in the opinion of its practical advocates. Holmes has informally defined conservation as "a wiser and more efficient use of the natural resources."[d]

Raymond states that "true conservation lies in the diminution, not of use, but of waste."[e]

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[a] McDowell, J. C., The conservation of natural gas: Proc. Nat. Gas Assoc. of America, 5th Ann. Meeting, 1910, pp. 104–113.

[b] Bull. N. Y. State Mus., vol. 6, November, 1899, pp. 483–487.

[c] Day, David T., Natural-gas resources of the United States: U. S. Geol. Survey, Bull. 394, 1909, pp. 51–61.

[d] Holmes, J. A., A rational basis for the conservation of mineral resources. Bull. Am. Inst. Min. Eng., February, 1909, p. 469.

[e] Raymond, R. W., The conservation of natural resources by legislation. Address before the Meeting of Engineers, in the Engineering building, New York City, March 24, 1909.

Holmes says that it is a misapprehension to think that the leaders of the conservation movement hope to bring about improvement entirely through legislation or executive orders, as neither of these agencies can be effective except as they are accompanied by both the necessary influences and the readjustment of economic or business conditions. The writers agree with him in this statement and also that "unwise restrictive legislation may do much more harm than good;" but nevertheless legislation should have been used long ago in many States to put an end to the waste of natural gas.

Hayes makes the following statement:[a]

"Disregarding the views of the extremists and visionaries, we may define conservation as utilization with a maximum efficiency and a minimum waste." Hayes lays particular stress upon the word *utilization*, regarding it as an essential feature of any form of practicable conservation.

During the last two years the shortage of gas in Kansas City, Mo., and in several Kansas cities has become so marked that fears have been entertained for the permanence of the supply, and Prof. Erasmus Haworth, of the University of Kansas, was engaged to make a report on the situation. His report, which unfortunately was not published, comprises seven volumes, entitled "Report on Natural Gas Conditions in the Mid-Continental Gas Field, Submitted to the Public Utilities Commission of Kansas City, Mo., November 21, 1911." The data given comprise the original rock pressure and original volume of flow, and the present rock pressure, and present volume of flow of wells in the individual fields. The fields covered were the Iola, Humboldt, Chanute, Vilas, Fredonia-Altoona, Cherryvale, Lahunt, Independence, South Independence, Coffeyville, Caney, Montgomery County, and California fields in Kansas and the Copen, Bartlesville, Hogshooter, Collinsville, Tulsa, Sapulpa, and Okmulgee fields in Oklahoma. Although other authorities believe the fields will last longer than Haworth believes, yet his report is a comprehensive statement of the necessity for preventing waste in those areas.

IMPORTANCE OF PREVENTING WASTE.

The importance of conserving natural gas, like other mineral resources of the country, can hardly be overestimated. The reasons may be summarized as follows:[b]

1. Natural gas is the cheapest and best fuel known to civilization.
2. The cities and towns in the vicinity of all discovered natural-gas fields have as a rule immediately perfected arrangements to make use of the supply.

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[a] Hayes, C. W., The conservation movement, Min. and Sci. Press, Nov. 19, 1910, pp. 664-668.

[b] The writers wish to give credit to Mr. Leon Smith, of the committee on the conservation of natural resources in Louisiana, for the summary of the importance of conservation, which was revised from the petition to the judges of the First Judicial District Court of Louisiana, to have the "wild" wells closed.

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3. Large amounts of money have been spent in piping the gas a distance of many miles from the wells and fields to points where the gas could be utilized.

4. Large amounts of money have been invested in building glass works, cement plants, and other industrial establishments in the vicinity of the great gas fields. These sums have been invested in the various regions solely because of the existence of natural gas there.

5. In many cases cities and towns of considerable size have grown up surrounding these plants on account of the existence of cheap gas, which has furnished, or is furnishing, employment to the people.

6. Cities and towns in the vicinity of the gas fields are in some cases wholly dependent on natural gas for fuel. Without the presence of this gas the various enterprises could not operate at a profit, and when the gas gives out they must stop operations or move away; and in any case the number of employees must be reduced at a considerable loss to large numbers of people.

7. In communities where gas has been and is being used for domestic fuel the houses have been specially constructed and would have to be equipped differently before other fuel could be used. Thousands of houses have had gas grates installed in every room without any hot-air registers or radiaters and with no place for a furnace, and such residences would have to be refitted at great expense in case of a failure of the gas supply.

8. The present cost of natural gas for lighting, cooking, and as fuel in gas regions is much less than that of any other fuel that can be procured, and gas is a wonderful source of convenience and comfort wherever it is used.

9. Many small towns and some large ones in or near every gas field have grown in population through the discovery of natural gas.

10. The wealth of any State where gas exists and the revenues being derived or derivable from taxation, on account of the existence of gas and the growth of population and of manufacturing, have greatly increased, and will correspondingly decrease in the event of the gas supply failing.

11. Large numbers of State and city institutions of considerable size have been equipped for the use of gas as fuel, resulting in great comfort to the occupants. To remove the equipment or to change to artificial gas, which is much more expensive, would result in great public loss.

12. If the movement to conserve properly the supply can be made effective, the continued use of natural gas will be increased by many years in all localities that are now supplied with it, and the prosperity of the various communities will be correspondingly increased

rather than decreased as they would be with a gas supply short lived because of present wasteful methods.

13. In an economic sense, the value of the gas wasted by permitting "wild" wells to flow into the air is hundreds of thousands of dollars per day. This is an absolute waste, as the gas going into the air can never be reclaimed.

14. In addition to the gas being lost the entire field in which any "wild" well is situated is greatly damaged by permitting the well to remain open, as the rock pressure is lowered, rapidly permitting the salt water to rise and stop the flow of gas from other wells.

15. In some regions, particularly in California and Texas, the gas is absolutely the only resource except oil, the climate or soil being such as to preclude the utilization of the territory for agricultural purposes. The best possible use should therefore be made of the more easily wasted of these two valuable products.

MEANS PROPOSED FOR MORE EFFICIENT UTILIZATION.

The means that have been proposed, and are hereby proposed, for conserving the natural-gas supply of this country may be classified as follows:

1. Precautions in drilling and casing wells.
2. Saving gas from oil wells.
3. Controlling and capping "wild" wells.
4. Proper care of the wells.
5. Most economic utilization of natural gas.
6. Better legislation.
7. Improved methods of use.
8. Prevention of leakage.
9. Increase in gas rates.
10. Use of meter system.

These various means will be considered separately.

PRECAUTIONS IN DRILLING AND CASING WELLS.

As previously stated, there may be some excuse for a single blowout or "wild" well in a new field where conditions are unknown, but there is seldom any excuse for a repetition of such a disaster in the same field, for it can be prevented by proper precautions in drilling.

In the Caddo field and in California and Texas the plan of "muddying" the well is followed. Instead of drilling with fresh water, a stream of very muddy water, in some cases almost pure mud, is pumped down the rotary pipe and allowed to rise outside this pipe. The mud collects in and clogs the pores of any sand penetrated by the bit.

In the California, Louisiana, and Mexico fields the plan of cementing around the casing is frequently adopted to safeguard the well. In the Caddo field the method seems not to have been used so extensively. Cement is sometimes used, however, in order to give the casing a firm seat on the cap rock. When the casing has been lowered into the well it is raised a few feet from the bottom and several barrels of cement are poured or pumped down,[a] after which water is forced down in order to pack the cement behind the casing. The latter is then dropped back on the cap rock, the cement allowed to set, and the well continued in the regular way. The use of cement is an effectual preventive of gas working up outside the casing, even if a flow of large volume be struck. The method is particularly applicable in the Caddo field on account of the soft cap rock there. Another use of cement is to assist in packing, the cement being poured on top of the packer outside the inner tube and allowed to set, thus holding the packer firmly in position.

In wells where a flow of more than 30,000,000 or 40,000,000 cubic feet of gas per day is expected, the size of the bit should be reduced just before drilling into the gas-bearing sand. Another precaution in all the gas wells in the Caddo field, and in some of the California and Texas fields, is to tie casings together with anchor rods and clamps. In a few cases "dead men" have been used as anchors.

SAVING GAS FROM OIL WELLS.

A great part of the present waste of gas is caused during oil production.

A common procedure of oil men is to carry the superfluous gas to a safe distance by a pipe connected to the well. Sometimes the gas is eliminated by burning, but a better plan is to use it in gas engines for pumping the wells or under boilers for power purposes.

Gas is sometimes led back into wells by means of pipes in order to force the oil to the surface. In one instance coming to the writers' notice in Texas the gas from a "duster" was used to blow the oil from several adjacent wells, $100 per day being received for the gas of this well alone. Unfortunately the gas was not saved for fuel after the utilization of its storage pressure.

A remedy for the waste during oil production is possible by proper cooperation between gas and oil companies. Such cooperation exists in West Virginia, Ohio, and Pennsylvania, where the gas companies and the oil companies are generally under the same management. Gas can be saved from oil wells by providing a prompt market for the gas. A partial solution is to compress natural gas in steel cylinders for transportation and for use on railroads and in automobiles.

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[a] Arnold, Ralph, and Garfias, V. R., The cementing process of excluding water from oil wells, as practiced in California. Technical Paper 32, Bureau of Mines, 1913, 12 pp., 1 fig.

The most economical use of the gas which comes from sands associated with the oil sands or from the oil itself is in making natural gasoline. In California, in particular, this use of the gas is growing rapidly. In one case $500 worth of gasoline is made daily from the gas which comes with the 2,500 barrels of oil from a single well. A movement is now on foot in the Santa Maria field in California to buy all of the gas now going to waste at 5 cents per 1,000 cubic feet and convert it into gasoline. Two hundred thousand feet per day, or even less, is sufficient to warrant installing a gasoline plant.

Both gas and oil can be saved when they flow from the same well, as is verified by the fact that this is done by a few progressive operators, who use a gas trap, which separates the oil and the gas by the gravity method. The great difficulty seems to be to find a market for the gas in a new oil field which has no natural-gas mains or other means of transportation at hand. It would seem that legislation might require the wells to be shut in until arrangements were made to bring gas lines to the oil wells, or until gasoline plants and other means of utilization were provided. If applied with discretion such legislation would work no injustice to the oil producer, as his ultimate profits would be larger through the sale of the gas. Some prominent gas producers with whom the writers have talked have stated that every legal and legislative means should be used to force the oil companies to save their gas, even "casing-head gas." They believe this can be accomplished without waste.

CONTROLLING AND CAPPING "WILD" WELLS.

The statement is frequently made that the so-called uncontrollable wells in Louisiana and other States can not possibly be controlled.

This statement is incorrect, as proved by the fact that one of the greatest "wild" wells ever known, the Gilbert, was successfully closed by the owners. According to information given the writers by M. B. Carmody, superintendent of the Caddo Gas and Oil Co., the method was as follows: Another gas well about 150 feet from the center of the crater of the "wild" well was drilled. An earthen reservoir of about 30,000 barrels capacity was constructed nearby, and was pumped full of clear water from Caddo Lake. This water was pumped from the storage reservoir into the new well for a few days; the pumps were then stopped, the well opened, and allowed to blow into the air for a few days. This procedure was to open a passage through the gas-bearing sand between the "wild" well and the new well, and was repeated continually until the crater of the "wild" well showed by its action that a connection had been established. The next step was to lower suction pipes into the new well and to pump in, from the reservoir, water containing a large amount of sediment. This water, being about 90 per cent mud, soon silted up the pores in the sand surrounding the crater of the "wild" well. As the pressure of the "wild" well became less the mud and water in the crater sank back to the bottom of the well and filled all open spaces in the sand, thus sealing off the gas.

The chief difficulty in closing this well is said to have been the great heat to which the workmen were exposed, as the gas in the crater was burning most of the time before the well was effectually closed. After the undertaking was finished the crater measured 300 feet in diameter by 90 feet deep.

In Oklahoma a 20,000,000-foot well in the Glenn pool caught fire and was put out after several weeks by a battery of boilers, which suffocated the flame with steam. The enormous burning well near Caney, Kans., was put out by J. C. McDowell, who made a large hood of boiler plate and by means of cranes and derricks dropped it on the well. The first attempt was not successful, as the hood was destroyed by the sand blast from the burning well.[a] All of the big gas wells of the famous Buena Vista Hills field, California, were got under control, even after catching fire; the usual method was to extinguish the fire by steam and then to shut the gas off gradually by means of heavy anchored valves. Evidently even the "wildest" burning wells can be effectually controlled by proper methods.[b]

The laws of Pennsylvania, Ohio, Indiana, and California provide for the efficient capping of every gas well when not in use. There should be similar laws in all States having gas fields. If the owners emphatically refuse to close their "wild" wells, the Louisiana remedy can be applied; that is, empower a State commission to close the wells and levy the cost on the companies. In Louisiana the commission on the conservation of natural resources, after making an exhaustive examination of the situation in the Caddo field, recommended—

> That the owners of the wild wells in the Caddo field be at once notified to take immediate steps to close the same;
>
> That in the event of their failure or refusal to do so, the State, through its engineering department, forthwith take steps to bring about control of the wells and stop waste at the expense of the owners;
>
> That if it be found that through failure of the law or otherwise the State can compel owners to bear the expense, then, and in that event, the State interest is sufficient to warrant the State in going to any reasonable expense to close the wells at the public cost.

The State of Louisiana has not been called upon to close any "wild" wells, for the reason that all but one have been closed by the owners, and in this one the gas escapes from a shallow sand, 900 feet above the supply which is used commercially. In March, 1912, no wells from the deep sand were running wild.

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[a] McDowell, J. C., The Maggie Vanderpool Oil and Gas Man's Magazine, July 23, 1908, pp. 41–48.

[b] A technical paper on the control of gas wells is to be published by the Bureau of Mines.

PROPER CARE OF THE WELLS.

One of the common causes of failing gas wells is the invasion of salt water. One method of prolonging the life of a well is to use only a fraction of the entire volume of gas that the well can produce, and thus maintain a back pressure high enough to keep out the encroaching water.

The rapid decline in certain Oklahoma fields is due to the large drain on wells by free flow or by pumps, as every company vies with every other to obtain the maximum possible yield of gas. Harry H. Breene is authority for the statement that the Kansas law prohibits the use of more than 50 per cent of the potential capacity of a well, but that such a regulation is utterly inadequate to meet conditions in Oklahoma, and has been proved utterly inadequate in Kansas. He says that salt water is the great danger in those fields, owing to the heavy drain on the wells. Where salt water will show in a month or less, as in the Hogshooter field, it is not safe to take over 15 per cent of the potential daily capacity of the well. Where there is a high rock pressure and the wells last a year or more without showing salt water, 50 per cent may be safely taken. Mr. Breene says that some companies have acted in disregard of section 7 of the Oklahoma act approved March 27, 1909, in drawing too heavily by the use of pumps, resulting in large inflows of salt water.

Mr. O. A. Evans of the Humboldt Gas Co., in a letter to Prof. Erasmus Haworth, dated October 24, 1911, writes as follows:

> We are able to keep many of our old wells alive by daily attention and by feeding them into the mains through half-inch to inch pipe, which reaches to the bottom of the wells. These small pipes we call "bleeders." They serve to relieve the well of water, as well as to convey the gas into the field lines. By this method we are able to keep our wells alive and producing a small supply of gas, using only a limited amount. The object of this is to hold the water back until the supply of gas is well exhausted. We find this fairly profitable but slow on a domestic rate of 25 cents per 1,000 feet.

The common method of ridding a gas well of accumulated water is to blow the gas into the air for a few minutes every morning. This is an unpardonable waste of gas, since the water may be cleared out by connecting a three-quarter inch siphon water line and pump with the well.[a]

However, where casing is used in place of tubing, a well can not be cleared in this manner. In case a gas well connected with a siphon becomes flooded with water, the siphon can be raised a few joints and the well shut in, then the pressure of gas can be allowed to accumulate and the well siphoned off through the water line. If this process be unsuccessful at first the three-quarter inch pipe can be repeatedly raised and the pressure allowed to accumulate until the water level is determined. When the water begins to flow, the pipe can be dropped back by stages to its original position.

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[a] Oliphant, F. H., Catalogue of Metric Metal Works, 1909, p. 100.

Unquestionably many gas wells are lost through a failure to clean them properly. After the grains of a gas sand have become coated with paraffin or salt near the well the only certain method of cleaning the well is by "steaming."[a]

In this process steam at a pressure of 125 pounds is turned into the three-quarter inch siphon after the well has been blown off through the tubing. The steam passes down the water line and returns up the tubing into the air. The boiler should be placed at least 200 feet from the well and on the windward side.

Another matter to bear in mind when the well is shut in is that it is not necessary to blow off a well as frequently in summer as in winter.

MOST ECONOMIC UTILIZATION OF NATURAL GAS.

In considering the problem of the conservation of natural gas, Hayes states:[b]

> The gas must be utilized, first, for the purpose for which it is most valuable; second, in the manner that will secure the greatest efficiency; and third, as near as possible to the point of production.

These three points will be taken up separately. The authors' conclusions differ somewhat from those reached by Hayes.

First. Although there are some lines of industry in which gas is of very great value, as, for instance, in the development of power, the writers believe that the most valuable use of ordinary gas at the present time is as domestic fuel. The truth of this can be understood from the fact that the domestic market is practically unlimited and that domestic consumers in different parts of the country can afford to pay as high as 15 cents to $1 per 1,000 cubic feet for gas. The ordinary price at which gas is sold in Louisiana and Oklahoma for manufacturing purposes ranges from 1 to 4 cents per 1,000 feet. Natural gas when used in an incandescent burner is one of the best illuminants known; furthermore it is the best domestic fuel. Hence, the desirability that public-service corporations should limit the sale of gas to domestic purposes as far as possible.

Second. Mr. Oliphant has stated[c] that the amount of gas required per hour for the development of a single horsepower varies from 9 cubic feet with the highest type of large internal-combustion engine to 130 cubic feet with the ordinary steam engine. This means that the efficiency of natural gas as a source of power is over fourteen times greater when used in gas engines than when burned under a boiler. The realization of this fact and the wider application of the gas engine would stop a large proportion of waste.

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[a] Oliphant, F. H., op. cit., p. 102.

[b] Hayes, C. W., The conservation movement: Min. and Sci. Press, Nov. 19, 1910, p. 666.

[c] Op. cit., p. 42.

Third. Although natural gas can be transported and is transported in pipe lines for hundreds of miles, the expense of such transportation is great, and in some cases the cost of installing the plants has prevented the companies from being remunerative. Expensive high-pressure pumping plants are necessary, and there is much loss of pressure by friction and some loss of gas by leakage.

In an economic sense it is cheaper for industries to move their plants to gas fields than to take gas piped hundreds of miles. Gas is at present pumped over 100 miles, however, from one station and with a consumption of fuel not exceeding 2½ per cent of the gas passed through the station.

Edward Orton [a] wrote 13 years ago:

> The truth is that natural gas ought to be exclusively confined to domestic use. * * * The amount of gas required in manufacturing necessitates the speedy decline and failure of every gas field, even the greatest. There is not a process to which it is turned, unless it be steam production, in which hundreds of thousands of feet, if not millions, are not demanded every day. For steam production 50 feet an hour for each horsepower is probably enough under careful and skillful use of the gas. This would make the consumption of a 50-horsepower engine working 10 hours a day 25,000 feet.
>
> For glass manufacture a 10-pot window-glass factory would be found to require about 600,000 cubic feet a day. A 10-pot flint-glass factory will use about 400,000 cubic feet a day.
>
> Ironworking demands by far the most lavish and unwarrantable use of gas of all manufacturing industries. A rolling mill will use from 1,000,000 to 5,000,000 feet a day. How far will 1,000,000 feet go in the support of household use? A house of 12 rooms, using gas in cooking range, laundry, furnace, and in six grates, uses on an average for the year about 40,000 cubic feet a month, or 1,333 feet a day. One million feet would supply 750 such establishments, or what the smallest rolling mill would use in a day would serve such a home for more than two years. But, instead of using 1,333 feet a day, the average residence will find all its necessities met by less than one-half the amount named. Five hundred feet will make an ample daily supply for the majority of city or village homes. * * *
>
> One of the evil results of the use of natural gas in manufactures is the development of the speculative fever called a "boom" in the towns that find gas at hand. Real estate feels the effect soonest. Inflated values derange legitimate prices, and the reactions that are inevitable are always hurtful.

The records of the Kansas Natural Gas Co. show that 43 per cent of the natural gas delivered is for manufacturing purposes.[b]

In the various cities and towns supplied by gas throughout Kansas and Oklahoma the proportion used by manufactories is even greater. When the gas supply is gone, the domestic consumer must go to the trouble and expense of installing furnaces, hot-air, hot-water, or steam plants, and the manufacturer must change to coal or to water power, or, if neither is available at a low rate, he must go out of business or move to another locality. Even from the point of view of the manufacturer it would frequently be cheaper

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[a] Bull. New York State Museum, vol. 6, November 1899, pp. 484-486.

[b] Letter to Erasmus Haworth, Sept. 8, 1911.

Original from PRINCETON UNIVERSITY

in the long run to use coal rather than gas. This statement applies to those companies that are obliged to buy gas from the distributing companies, as when they own their wells the cost of obtaining gas is much less. But a great many of the industrial plants that now use gas meet with partial failure when the supply wanes.

When the quality and yield of gas render the process feasible, the gas should be condensed into gasoline; this can be done at the well thereby preventing any loss from transportation, and the product can be stored cheaply and for an indefinite period.

BETTER LEGISLATION.

In order to clearly understand the legal phases of the problem of conserving gas, one must first obtain a clear comprehension of the manner in which gas occurs in nature and its legal standing. Natural gas is a mixture of carbon, hydrogen, and oxygen compounds, the chief constitutent generally being methane or marsh gas. The mixture contains also free hydrogen and free nitrogen; hydrogen sulphide and carbon dioxide also exist. The gas occurs in the pores of stratified rocks, usually sandstones or limestones, overlain by an impervious cover, shale, limestone, or clay, and confined laterally by the geologic structure of the beds or by adjacent pools of water or oil, or harder and denser phases of the porous strata. It should be understood that gas is free to move laterally to some extent, but usually can not move vertically until a well be drilled to tap it. Oil and gas are believed to be organic compounds, but their legal status as minerals has been settled again and again in court decisions. As stated by Thornton:[a]

> The status of gas and oil has, however, been settled as different from other minerals on account of their wandering nature, and for this reason they have been classed with animals, which have the power and tendency to escape without the volition of their owner. They belong to the owner of the land and are a part of it, and are subject to his control, but when they escape and go into other land or come under another control the title of the former owner is gone.

The wandering nature of gas is one cause of its waste and apparently of the many legal and legislative difficulties involved in preventing waste. Since the United States Government has no powers to stop waste, except on Government land, the various States should enact such laws. In Indiana a law was put into effect in 1896. In the opinion of some authorities:[b]

> The statute of Indiana for the conservation of oil and natural gas should be enacted into law in every State where oil and gas are produced. It will be opposed by some oil producers and large oil corporations; they will assert that they can not produce oil and save the gas; that their individual rights are being trampled on, etc. In a recent conversation on the subject, the manager of one of the largest oil companies operating in Indiana said to the writer that he approved of the Indiana law for the prevention

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[a] Thornton, W. W., Law relating to oil and gas. Cincinnati, 1904, p. 34.

[b] McDowell, J. C., op. cit., pp. 110–111.

of waste of gas; that he had experienced no great difficulty in operating oil wells in Indiana under that law; and that no oil producer ought to object to the passage and enforcement of such a law.

The writer can point to a large number of wells whose oil and gas are both being produced from the same well, the gas being separated from the oil and delivered into large mains, at high pressure, by means of compressors.

Legislation has been effective to some extent in Indiana, Ohio, and Pennsylvania, yet the credit of overcoming the waste there is due not wholly to legislation, but largely to the attitude of the companies themselves, the officials of which have tried to economize in various directions. Waste in these States has practically ceased.

The Indiana statute, which has been declared constitutional by our highest courts, says, in effect, to the oil producers, "You can not take the oil from the ground, where nature has safely stored it, until you provide a method of separating and utilizing the accompanying gas, or volatile oil as well, and it also says to both the producer and and the consumer of natural gas, that it is against *public policy* to waste this valuable fuel and that it will not permitted."[a]

In the State of West Virginia there is no law against waste. The Louisiana law is modeled after the Indiana law, and would be effective but for the fact that the oil companies have obtained injunctions to prevent enforcement, claiming the taxation clause to be unconstitutional. The companies object to paying a tax of one-fifth of 1 cent per 1,000 cubic feet of gas produced.

In order that legislation may be effective, it should have regard for the fact that producing companies as well as consumers have rights, and it should be enforced by conscientious public officials, who will attend to their duty. There have been many instances of foolish legislation by city councils and by State legislatures which sought to give better service, without regard to the true condition of the natural-gas business and the difficulties under which the companies are working.

As an example may be mentioned an unsuccessful attempt made by the citizens of a Pennsylvania city to compel the gas company to extend its mains on certain streets. The company refused on the ground that the supply was not sufficient to warrant any further extensions and the court upheld that contention. The company claimed it had endeavored to procure more gas, but had been unable to do so. Equally foolish legislation has been noticed in a great many cities where the councils have tried to lower the gas rates, when as a matter of fact they should have been increased to insure the highest efficiency and to prolong the service for years. Whatever may be the opinion of the general public in the matter, it is a fact that the rates charged by public-utility corporations for natural gas in this country are in most cases too low rather than too high, and that the most efficient regulation can be successfully accomplished only by raising rates to such a point that consumers will not waste gas.

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[a] White, I. C., Address at the Conference on Conservation of Natural Resources, held at the White House, May 13, 1908, p. 12.

IMPROVED METHODS OF USE.

A part of the gas waste could undoubtedly be prevented by the use of the most improved forms of grates, burners, and mantles in domestic consumption. If natural gas for lighting be consumed with an ordinary tip, 7 or 8 cubic feet per hour will yield 6 candlepower. If a good mantle is used, 2½ cubic feet of gas per hour will yield 50 candlepower.[a] Assuming the cost of gas at 25 cents per 1,000 cubic feet, the cost per candlepower per hour in the former case will be 0.01146 of 1 cent, and in the latter case 0.00125 of 1 cent, about one-tenth of what the cost is without the mantle. All natural gas, however, does not give the same figures, because of variations in illuminating power. The burning of gas in Welsbach and similar incandescent mantles for lighting houses is a very efficient manner of utilization. Burning in stoves or grates is generally fairly efficient, but there is usually some waste due to carelessness or a lack of knowledge of the consumer.

Robert W. Goodnow, city gas inspector of Kansas City, Mo., has issued a booklet of suggestions to domestic consumers in which he writes as follows:

> Our experience teaches us that in a great many cases high gas bills are due to the fact that the air mixers on the kitchen stove have been closed or are filled with dust or dirt, so that the gas does not get sufficient air mixed with it before it reaches the burner to produce proper combustion. A yellow-tipped flame, or the pots and pans when placed directly over the fire blackening any, will inform you that you are not obtaining the results you should obtain with the same amount of gas were it properly burned.

A gas engine utilizes gas much more efficiently than a boiler and a steam engine, and gas engines should be more widely used to generate power. In order to show the economy of the internal-combustion engine, Oliphant has given the following table:[b]

Average amount of natural gas required to operate gas engines or to supply a steam-engine plant using natural gas as fuel under the boilers, in cubic feet per indicated horsepower per hour.

	Cu. ft.
Large gas engine, highest type	9
Ordinary gas engine	13
Triple-expansion condensing steam engine	16
Double-expansion condensing steam engine	20
Single-cylinder steam engine with cut-off	40
Ordinary high-pressure steam engine without cut-off	80
Ordinary oil-well pumping steam engine	130

From 10 to 12 cubic feet of air is necessary for the complete combustion of 1 cubic foot of natural gas.

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[a] Oliphant, F. H., Catalogue of Metric Metal Works, p. 42.

[b] Op. cit., p. 42.

PREVENTION OF LEAKAGE.

It seems almost needless to call attention to the necessity of keeping pipe lines in good condition to prevent the escape of gas; but it is a fact that certain pipe lines are in very bad condition, being not only wasteful but dangerous as well.

INCREASE IN GAS RATES.

As long ago as 1899, Orton[a] wrote:

> The price of [natural] gas ought to be increased in every community that is now using it. There is no good reason why it should be sold at any less price than the fuel which it displaces, or, in other words, why the better article should be sold for less than the inferior. In computing the cost of the displaced fuel, account should always be taken of the various items involved, such as its storage and preparation, the cost of lighting fires and the expenses of removing ashes and cinders, none of which enter into the use of gaseous fuel. It may be urged that an increased price for gas would result in extravagant profit for the gas companies. It can not be denied that there is a possibility of such a result, but as a matter of fact there are very few cases in the country in which companies have got back their original investment or see any good chance of getting it back. They are generally obliged to content themselves with generous dividends while the gas is in full flow.

The above statement by Dr. Orton still held true in 1912. Although in many places the rates charged for artificial gas are too high, natural-gas rates, on the other hand, are, and always have been, inexcusably low.

In all communities that have the use of natural gas the companies have endeavored at some time to raise the rates, and the city councils have legislated for a lower rate. Although in a few cases one or the other party has surrendered without a legal battle, in others the question has gone to the courts—sometimes because of a threat of the companies to turn off the gas unless a price of their making were given. Such agitation generally comes up when the public-service company applies for an extension of its charter. Although there is little doubt that the municipal legislators believe they are doing their constituents a service by forcing low rates, it must be acknowledged that all cases brought to lower the rates have met with failure, as the courts have justly upheld the companies in their attitude. Where the rates have been increased, the excuse for doing so has been generally warranted by diminishing supplies or necessity of piping from more distant fields.

This truth is approved by Knapp, who writes as follows, referring to the Kansas City gas controversy:[b]

> If Professor Haworth will advise his clients, the city of Kansas City, Mo., and other cities, to put the retail price of gas up to 50 cents, and they act on his advice, it will bring about a whole lot of true conservation; that is, the price will be so remunera-

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[a] Bull. New York State Museum, vol. 16, November, 1899.

[b] Knapp, I. N., in a letter to the Oil and Gas Jour., Oct. 26, 1911.

tive that the gas-piping companies can go and outbid the brick, the cement, and the smelter companies, and buy the gas to hold it for domestic consumption. Then it will be worth so much that it will pay the oil operator to save his gas for the gas companies and not use it direct under boilers or for blowing oil wells. * * *

The only wise way for the cities to do is to allow the gas companies sufficient price so that they can afford to prospect for, buy, and hold gas territory for the present and future use. * * *

Knapp sums up his conclusions in these words: "Show the profit, and conservation will take care of itself." [a]

USE OF METERS.

It is estimated that 60 to 70 per cent of the gas consumed or wasted when gas is sold under a flat system may be saved by changing to a meter system. The saving can be attributed to several causes, as follows: [b]

1. With a flat-rate system the consumers invariably use cheap and wasteful burners.
2. When the pressure is low consumers will sometimes drill out the mixer in an endeavor to obtain a larger supply of gas.
3. They take no care to turn off the gas when finishing work or when the temperature of the house is sufficiently high.
4. When the temperature is high enough the consumers have a tendency to open doors and windows in preference to turning down the fire.
5. Fires and lights are left burning night and day because it is easier to leave them burning than to turn them off.
6. Under the meter system the pipe in the house can be tested for leaks by turning off fires and lights, and noting by the meter dial whether there is gas passing through it.
7. The life of any gas field may be prolonged several years by using a meter system instead of a flat-rate system.

RELATION OF GAS WELLS TO COAL MINING AND THE SAFETY OF MINES.

In discussing the conservation problems we should not neglect those problems that involve the conservation of other resources through the production of natural gas. Hence it must be said that the gas industry involves also the safety of any mines that may exist or be subsequently opened in the vicinity of gas wells. A number of prominent engineers hold the opinion that certain disastrous coal-mine explosions have been caused by the leakage of gas into mines from existing or abandoned wells through improper plugging and casing.

White [c] has called attention to the possibility of some mine explosions having been caused by gas that escaped from abandoned wells. As a remedy he proposed that "not a single string of casing that has penetrated the productive coal measures in the oil and gas regions of the States where natural gas is encountered in any appreciable quantity should ever be pulled out until the underlying coal has been removed."

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[a] Knapp, I. N., in a letter to Prof. Erasmus Haworth, Rept. on Mid-Continent fields, vol. 3, p. 69.

[b] Oliphant, F. H., op. cit., p. 123.

[c] White, I. C., Address before the American Mining Congress, Pittsburgh, Pa., Dec. 5, 1908.

Three years later the same writer mentioned an accident[a] in which an explosion near Fairmont, W. Va., was caused from a gas well which though shut in had leaked into this mine and into another mine separated by a barrier pillar, through a distance of some 1,500 feet, the gas rising through joints or other cracks in the floor of the mine.

Hundreds of wells in West Virginia and Pennsylvania have been drilled through the Pittsburgh coal bed. The wells should be plugged properly, and, as suggested by White,[b] the most effective means will be to fill them with cement, according to the law in England and in France. The State of Ohio has a law that requires every hole drilled through a workable coal bed to be filled, when abandoned, with cement for 30 feet below the floor of the bed and for 20 feet above. The Ohio law also dictates how the casing shall be placed in wells which are in use. It might be advisable to go a step in advance and fill all holes from top to bottom as is required in England and France. Such provision would solve a number of difficulties in relation to mining and would insure effective plugging.[c]

Much of the natural gas in the Texas fields is poisonous and all natural gas is suffocating and inflammable. Hence the waste of large quantities of gas is always accompanied by more or less danger to human life, so that for this reason, too, its dissipation should be controlled.

PUBLICATIONS ON PETROLEUM TECHNOLOGY.

The following Bureau of Mines publications may be obtained free by applying to the Director, Bureau of Mines, Washington, D. C.:

BULLETIN 19. Physical and chemical properties of the petroleums of the San Joaquin Valley, Cal., by I. C. Allen and W. A. Jacobs, with a chapter on analyses of natural gas from the southern California oil fields, by G. A. Burrell. 1911. 60 pp., 2 pls., 10 figs.

TECHNICAL PAPER 3. Specifications for the purchase of fuel oil for the Government, with directions for sampling oil and natural gas, by I. C. Allen. 1911. 13 pp.

TECHNICAL PAPER 10. Liquefied products from natural gas; their properties and uses, by I. C. Allen and G. A. Burrell. 1912. 23 pp.

TECHNICAL PAPER 25. Methods for the determination of water in petroleum and its products, by I. C. Allen and W. A. Jacobs. 1912. 13 pp., 2 figs.

TECHNICAL PAPER 26. Methods of determining the sulphur content of fuels, especially petroleum products, by I. C. Allen and I. W. Robertson. 1912. 13 pp., 1 fig.

TECHNICAL PAPER 32. The cementing process of excluding water from oil wells as practiced in California, by Ralph Arnold and V. R. Garfias. 1913. 12 pp., 1 fig.

TECHNICAL PAPER 36. The preparation of specifications for petroleum products, by I. C. Allen. 1913. 12 pp.

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[a] Proc. Nat. Gas Assoc. of America, 6th Ann. Meeting, 1911, p. 172.

[b] Op. cit., p. 173.

[c] For a discussion of the plugging of gas wells, see Bulletin 65, Bureau of Mines.

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